This publication presents the methods and resources needed to conduct a Cleaner Technologies Substitutes Assessment (CTSA), a methodology for evaluating the comparative risk, performance, cost, and resource conservation of alternatives to chemicals currently used by specific industry sectors. The CTSA methodology was developed by the U.S. Environmental Protection Agency (EPA) Design for the Environment (DfE) Program, the University of Tennessee Center for Clean Products and Clean Technologies, and other partners in voluntary, cooperative, industry-specific pilot projects.

EXECUTIVE SUMMARY

Part I of this publication is an overview of the CTSA process, including the preparatory steps leading up to a CTSA, and the types of data collected and analyses performed in a CTSA. Part II describes the data sets and analyses in more detail.

Businesses operating in the 1990s face a variety of competing demands — maintaining high quality at low cost, staying competitive in a global marketplace, and meeting consumer preferences and regulatory demands for reduced environmental impacts. Designing for the environment is an effective strategy for organizing and managing these challenging demands.

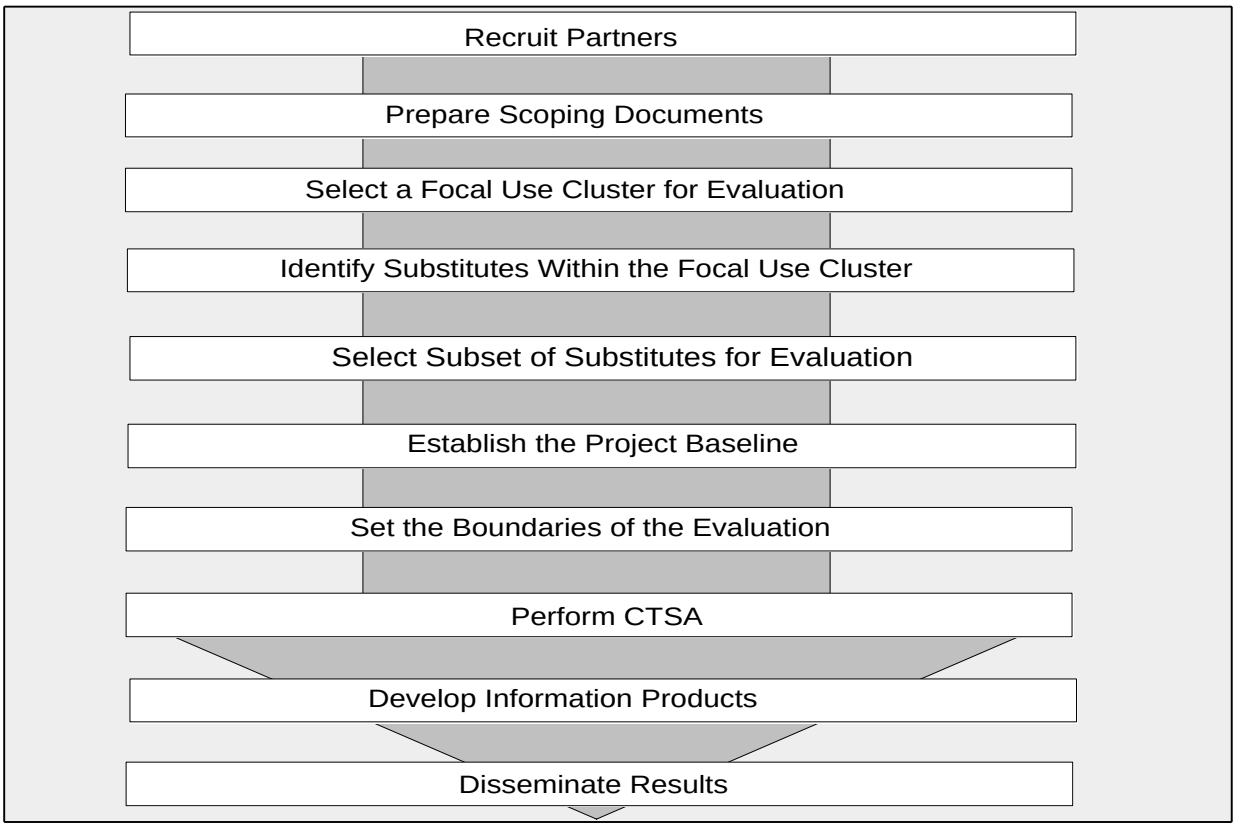
The EPA Office of Pollution Prevention and Toxics created the DfE program in 1991 to help businesses incorporate environmental considerations into the design and redesign of products, processes, and technical and management system. DfE projects include broad institutional efforts aimed at changing general business practices, as well as voluntary, cooperative projects with trade associations and businesses in specific industries.

A typical industry project includes developing a CTSA and a communication and implementation strategy. The CTSA *methodology* has grown out of DfE industry projects, which are cooperative, joint efforts with trade associations, businesses, public-interest groups, and academia to assist businesses in specific industries to select more environmentally-sound products, processes and technologies. A CTSA *document* is the repository for the technical information developed by a particular DfE project, including detailed environmental, economic, and performance information on traditional and alternative chemicals, manufacturing methods and technologies. A CTSA does not recommend alternatives or make value judgements concerning an alternative. Instead, the goal is to provide businesses with information to make environmentally informed choices and design for the environment.

STEPS IN A CLEANER TECHNOLOGIES SUBSTITUTES ASSESSMENT PROJECT

Figure ES-1 illustrates the basic steps leading up to and following a CTSA. First, DfE project organizers recruit partners from various stakeholder communities to create a project team. Past CTSA project teams have been convened by EPA together with trade associations, industry research organizations, or other concerned representatives of the business community seeking to reduce the environmental impacts of their products and manufacturing processes. A goal of this publication, however, is to provide businesses, public-interest groups, and other stakeholders the information they need to perform comparative evaluations with or without the direct participation of EPA.

FIGURE ES-1: STEPS IN A CTSA PROJECT



Once a project team is assembled, the team members develop an Industry and Use Cluster Profile document and a Regulatory Profile document to help define the project focus. An Industry and Use Cluster Profile gives market data for the industry, describes technological trends, and presents a summary of key industry processes, individual steps within processes, chemicals typically used in each step, and a preliminary list of substitutes for each step. These sets of substitutes make up the *use clusters* for the industry. A *use cluster* is a product- or process-specific application in which a set of chemical products, technologies, or processes can substitute for one another to perform a particular function. A Regulatory Profile identifies the principal federal environmental regulations that may affect the industry under study and the factors that

determine which regulations apply to any particular operation. The project team typically selects the use cluster with the greatest opportunities for environmental improvement for the detailed analysis of a CTSA.

Identifying Substitutes

Additional substitutes are identified as a CTSA progresses and more information is gained about the characteristics of the use cluster and of the industry. All stakeholder groups are potential sources of information about additional substitutes. For example, manufacturers and suppliers of chemical products and technologies play an important role in substitutes identification, since they frequently have an up-to-date understanding of current industry trends, and emerging products or technologies. Also, the participation of suppliers in the CTSA process is essential to developing information on chemical product formulations, which is used in the risk characterization

Trade associations frequently track new developments; universities and other research organizations may be involved in applied or basic research on new alternatives. Public-interest groups concerned about human health risk or other environmental impacts may have independently searched for options to prevent pollution. DfE project teams use all of these resources to develop a *substitutes tree*. A *substitutes tree* is a graphical depiction of the substitute or alternative chemical products, technologies, or processes that form the use cluster and their relationship to each other within the functional category defined by the use cluster. In a DfE project, the terms *substitute* and *alternative* are used interchangeably to mean any traditional or novel chemical product, technology, or process that can be used to perform a particular function.

Establishing the Baseline and Boundaries of the Evaluation

Due to time and resource constraints, the project team may select a subset of substitutes for detailed evaluation in a CTSA. Past CTSAs have evaluated a subset of currently available substitutes, including substitutes that have not yet been widely adopted by industry. The project baseline(s) are substitute(s) that are currently industry standard practice or familiar to most of the industry, which come from this subset. With a familiar baseline as the basis for comparison, the comparative data on risk, performance, cost, and conservation developed through the project will be understandable to the majority of industry.

Once the subset of substitutes and baseline(s) are established, the boundaries of the evaluation are set by identifying the life cycle stages and types of environmental impacts (i.e., human health and environmental risk to workers, energy impacts, etc.) of greatest concern. Past CTSAs have focussed on the areas where the project partners can most influence change, in the use and disposal of chemicals at operating facilities. The project team is then ready to perform the detailed data collection and analysis needed to develop a CTSA (see below).

Disseminating Results

Following completion of a CTSA, DfE project partners develop a variety of outreach tools to communicate CTSA results. These may include fact sheets, bulletins, pollution prevention case studies, software, videos, and training materials. CTSA results are disseminated to businesses and other stakeholders to encourage businesses to consider and use cleaner products, processes, and technologies.

DEVELOPING A CLEANER TECHNOLOGIES SUBSTITUTES ASSESSMENT

A CTSA uses *information modules* to develop as complete and systematic a picture as possible of the comparative risk, competitiveness (i.e., performance, cost, etc.), and resource conservation of the substitutes in a use cluster. An *information module* is a standard analysis or set of data designed to build on or feed into other information modules to form an overall assessment of the substitutes. A CTSA records and presents facts collected in the information modules, but does not make value judgements or advocate particular choices.

Figure ES-2 describes the basic process for developing a CTSA. The technical work typically starts with the collection of basic chemical properties and process information, followed by the collection of risk, competitiveness, and conservation data. At the same time, the project team develops methodologies for data analysis to ensure that all necessary data are collected. The next step is to analyze the collected data to determine the relative human health and environmental risk, competitiveness, and resource conservation of alternatives. Past DfE projects have shown that the choice of an alternative will frequently involve making trade-offs. For example, when compared to the baseline, an alternative may cost slightly more, but have substantially reduced risk. The trade-off issues are evaluated to determine the relative benefits and costs of an alternative from both an individual perspective and a societal perspective. All of this is performed through the completion of 22 information modules, shown as bullets in Figure ES-3.

Table ES-1 presents an overview of each of the information modules listed in Figure ES-3. Part II of this publication describes each of these modules in more detail, including a summary of the step-by-step process for completing a module, and sources of data, analytical models, and previously published guidance helpful in completing a module. Since the CTSA process is applicable to numerous industry sectors, the module descriptions were developed to provide basic information suitable for a wide audience with a broad range of information needs. The descriptions should give a DfE project team a basic understanding of the analytical concepts and methodology for completing a module, but they do not give a complete accounting of all of the assumptions, analytical methods or steps required for some of the more complicated analyses, such as exposure assessment.

For the more complicated analyses, a DfE project team should refer to published guidance, with references provided in the module descriptions. In addition, many of the modules describe analyses or data evaluations that cannot be performed without substantial expertise and

experience (e.g., the Human Health Hazards Summary, Environmental Hazards Summary, Exposure Assessment, and Risk Characterization modules). For these and other analyses, users of this publication who do not have the necessary expertise are urged to seek outside assistance.

FIGURE ES-2: STEPS TO DEVELOP A CTSA

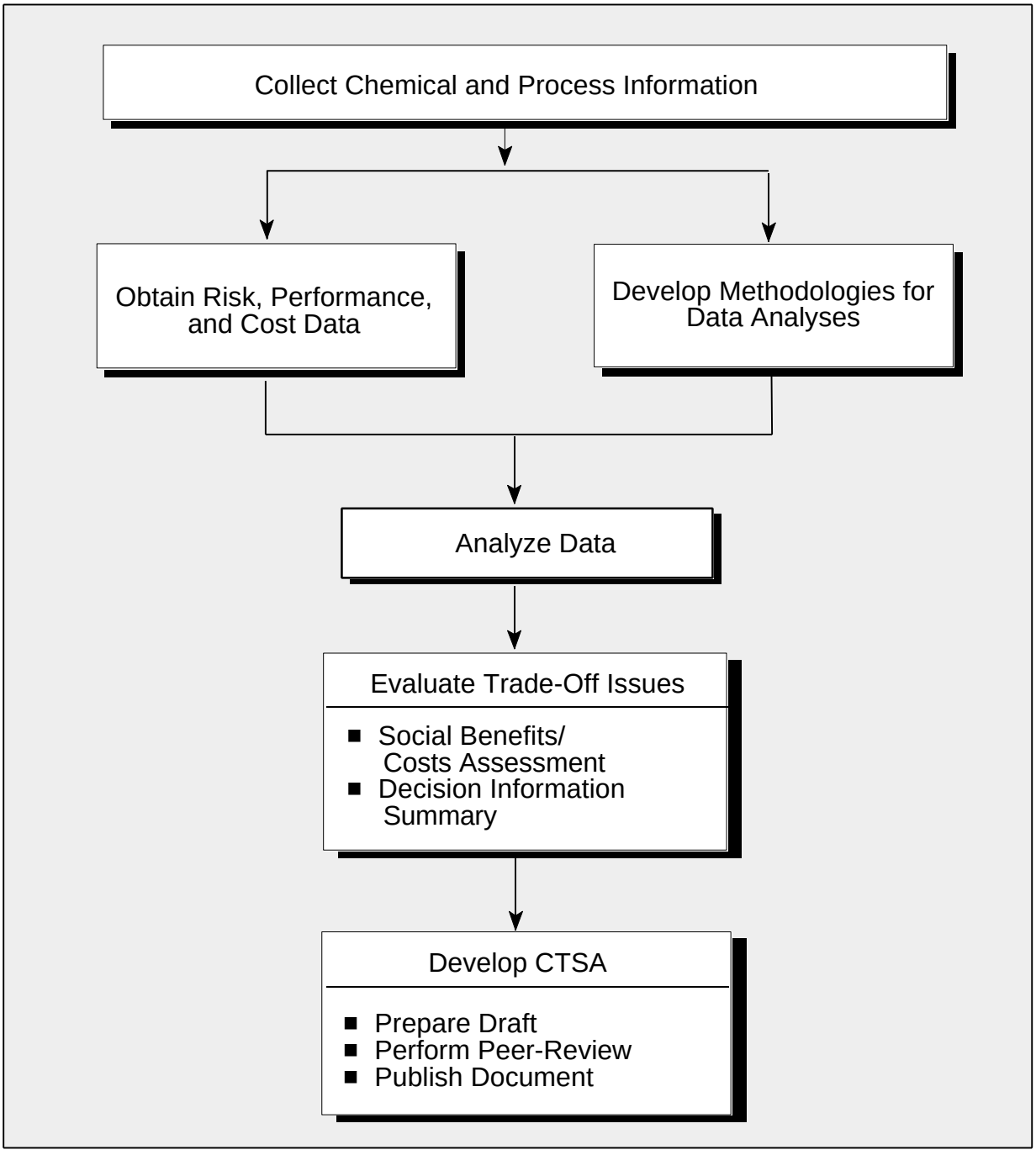


FIGURE ES-3: CTSA INFORMATION FLOWS

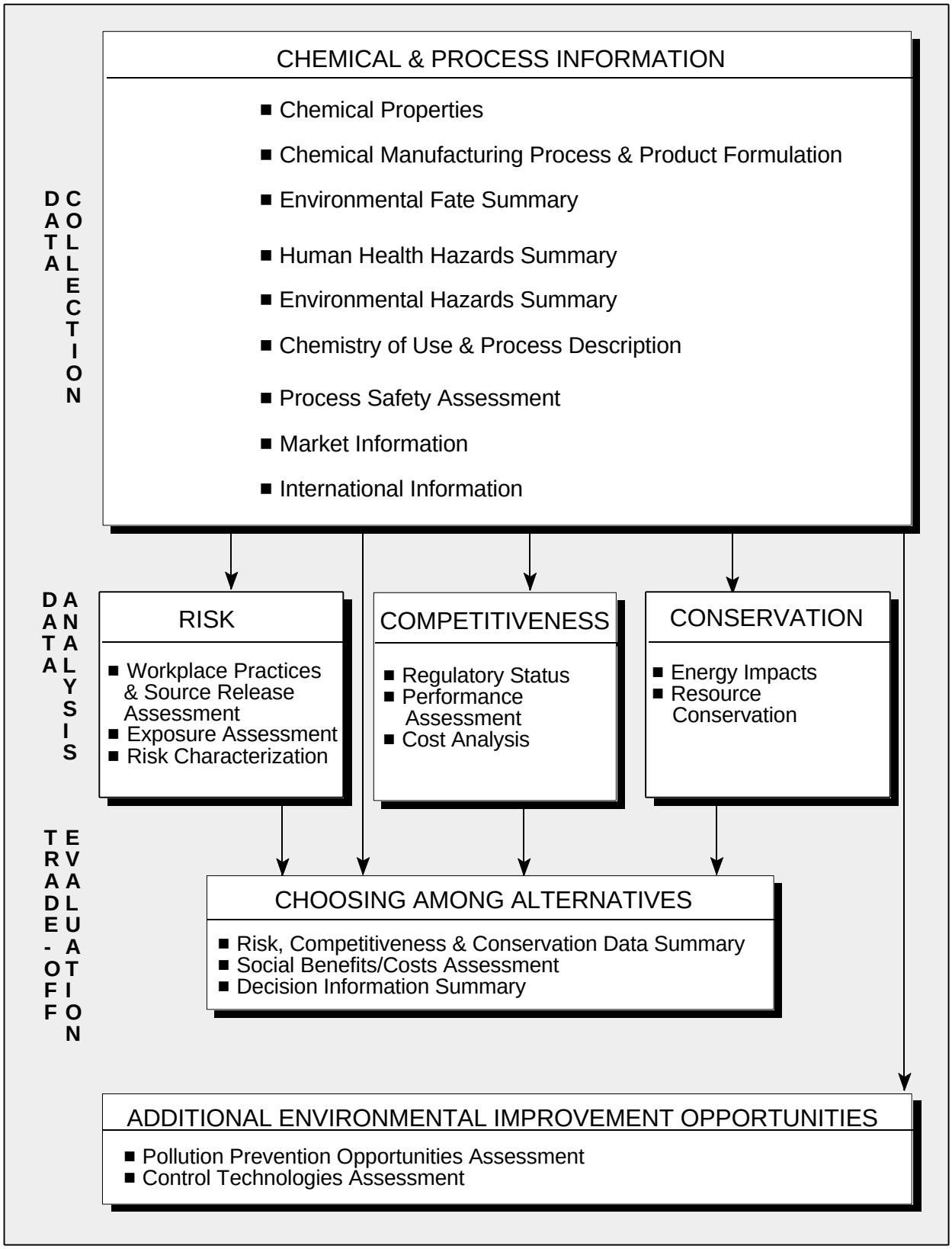


TABLE ES-1: OVERVIEW OF CTSA INFORMATION MODULES		
Component	**Module**	**Overview**
Chemical & Process Information	Chemical Properties	The chemical and physical properties of a substance are characteristics which identify it from other substances. In this module, the physical and chemical characteristics of the chemicals in the use cluster are detailed.
	Chemical Manufacturing Process & Product Formulation	The Chemical Manufacturing Process & Product Formulation module describes: (1) the process for manufacturing the chemicals in the use cluster; and (2) the chemical product formulation process, if applicable. Past CTSAs have qualitatively described these processes. However, if up-stream processes are being quantitatively evaluated in a CTSA a more quantitative description would be needed.
	Environmental Fate Summary	The environmental fate of chemicals describes the processes by which chemicals move and are transformed in the environment. Some of the processes that should be addressed include: persistence in air, water, and soil; reactivity and degradation; migration in groundwater; removal from effluents by standard waste water treatment methods; and bioaccumulation in aquatic or terrestrial organisms.
	Human Health Hazards Summary	Human health hazards assessment is the process of identifying the potential effects that a chemical may have on humans who are exposed to it, and of determining the levels at which these effects may occur. Exposure to a chemical may occur by inhalation, oral, or dermal routes through the production, use, or disposal of the chemical or products containing the chemical. Human health toxicity data are combined with data from the Exposure Assessment module to assess human health risk in the Risk Characterization module.
	Environmental Hazards Summary	Environmental hazards assessment is the process of identifying the adverse effects that a chemical may have on organisms in the environment. Currently, the CTSA process for environmental hazards assessment focuses on aquatic toxicity. This module collects data on measured or predicted toxicity of chemicals to aquatic organisms to characterize potential hazards of chemical discharges to receiving waters. Toxicity data are combined with data from the Exposure Assessment module to assess ecological risk in the Risk Characterization module.
	Chemistry of Use & Process Description	The Chemistry of Use & Process Description module identifies: (1) the chemical/physical properties which contribute to the effectiveness of the chemicals in the use cluster; and (2) the process in which the chemicals are used. A process flow diagram is created that schematically describes the process operations, equipment, and material flows.
	Process Safety Assessment	The Process Safety Assessment module screens potential chemical substitutes to determine if they could potentially pose a safety hazard in the workplace. Process operating characteristics and workplace practices are combined with physical hazard data, precautions for safe handling and use, and other data to determine if a substitute might pose a safety hazard.
	Market Information	The Market Information module contains economic data used to evaluate the importance of the target industry sector to the overall market and conversely, the economic importance of the alternatives to the industry sector. Market information includes chemical/technology cost information, production, and manufacturing volumes, and an analysis of market trends that could affect future supply and demand.
	International Information	The International Information module collects data pertaining to the use or production of alternatives in other parts of the world, the impact of international trade on the selection of alternatives, and the impacts of switching to an alternative on international trade. Primarily, international trade issues are driven by the source and availability of alternatives and possible indirect costs (e.g., taxes, tariffs, etc.) imposed on alternatives.

TABLE ES-1: OVERVIEW OF CTSA INFORMATION MODULES		
Component	**Module**	**Overview**
Risk	Workplace Practices & Source Release Assessment	The Workplace Practices & Source Release Assessment module identifies: (1) the workplace practices that contribute to environmental releases and worker exposure; and (2) the sources, amounts, and characteristics of environmental releases.
	Exposure Assessment	Exposure assessment is the quantitative or qualitative evaluation of the contact an organism (human or environmental) may have with a chemical or physical agent, which describes the magnitude, frequency, duration, and route of contact.
	Risk Characterization	Risk characterization (also referred to in the CTSA process as risk integration) is the integration of hazard and exposure information to quantitatively or qualitatively assess risk. Risk characterization typically includes a description of the assumptions, scientific judgments, and uncertainties that are part of this process.
Competitiveness	Regulatory Status	The Regulatory Status module determines the statutes and regulations that govern a particular chemical or industrial process.
	Performance Assessment	The Performance Assessment module measures how well a substitute performs to meet the functional requirements of the use cluster. In order to allow a comparative evaluation of the performance of baseline products or processes with the performance of substitutes, performance data are collected for both. This module provides assistance in developing methodologies for obtaining comparative performance data.
	Cost Analysis	The Cost Analysis module identifies the costs associated with the baseline process, as well as suitable substitutes, and calculates comparative costs between the baseline process and the substitutes. As a minimum, the cost analysis should identify the direct costs of the baseline process and the substitutes. If time and resources permit, data are also collected on indirect and future liability costs as well as any less-tangible benefits that occur through the implementation of a substitute.
Conservation	Energy Impacts	Energy consumption, either during the manufacture of a chemical or the use of a substitute product, process, or technology can vary with a selected chemical or process change. This module provides a procedure for evaluating the energy impacts of substitutes in a use cluster.
	Resource Conservation	Resource conservation is the process of selecting and using products, processes, or technologies that minimize the overall consumption of resources while effectively achieving a desired function. This module addresses materials use rates and provides methods for identifying the relative amounts of resources or materials consumed as a consequence of changing from a chemical, process, or technology to a substitute.

TABLE ES-1: OVERVIEW OF CTSA INFORMATION MODULES		
Component	**Module**	**Overview**
Additional Environmental Improvement Opportunities	Pollution Prevention Opportunities Assessment	Pollution prevention is the process of reducing or preventing pollution at the source through changes in production, operation, and raw materials use. This module provides methods for identifying pollution prevention opportunities that can provide additional benefits beyond the benefits realized if one of the alternatives evaluated in the CTSA is implemented.
	Control Technologies Assessment	Control technologies are methods which can be used to minimize the toxicity and volume of pollutants. This module provides methods for identifying control technologies that may be suitable for on-site treatment and disposal of product or process waste streams.
Choosing Among Alternatives	Risk, Competitiveness & Conservation Data Summary	The Risk, Competitiveness & Conservation Data Summary module organizes data from the risk, competitiveness, and conservation components of a CTSA together with data from the Process Safety Assessment, Market Information, and International Information modules to: (1) identify the trade-off issues associated with any one substitute; and (2) compare the trade-off issues across substitutes. Data summaries are transferred to the Social Benefits/Costs Assessment and to the Decision Information Summary modules for further analysis.
	Social Benefits/ Costs Assessment	Social Benefits/Costs Assessment is the process of qualitatively and systematically evaluating the impacts made on all society by individual decisions. Social benefits/costs assessment includes the benefits and costs to the individual of alternative choices (referred to as private benefits and costs) and the benefits and costs to others who are affected by the choices (referred to as external benefits and costs). Consideration of these effects in decision-making by industry could result in improvements for industry and society as a whole.
	Decision Information Summary	The Decision Information Summary is the final module of a CTSA. It combines the results of the Risk, Competitiveness & Conservation Data Summary with the Social Benefits/Costs Assessment to identify the overall advantages and disadvantages of the baseline and the substitutes from both an individual business perspective and a societal perspective. The actual decision of whether or not to implement an alternative is made by individual decision-makers outside of the CTSA process, who typically consider a number of other factors, such as their individual business circumstances, together with the information presented in a CTSA.

BENEFITS OF A CLEANER TECHNOLOGIES SUBSTITUTES ASSESSMENT

DfE partnerships developed the CTSA methodology described in this publication to help business decision-makers achieve the tangible benefits that result from using a cleaner product or technology. CTSA results give businesses the information needed to improve their bottom line by evaluating and documenting voluntary changes a business can make to prevent pollution and reduce risk. Pollution prevention often lowers cost by reducing the amount of materials used in production processes, the amount of waste streams that must be treated and disposed, and by improving worker health and safety. In addition, a CTSA provides the necessary information for companies to make informed business decisions that may reduce their regulatory burden or potential liability costs. Also, companies that make voluntary changes to prevent pollution or reduce risk may enjoy increased acceptance and market share from environmentally conscious consumers.

Businesses that participate in voluntary DfE initiatives demonstrate their commitment to continuous environmental improvement. Company employees involved in day-to-day operations ensure the project team understands the process constraints that need to be considered in the design of environmentally preferable options. Stakeholder communities outside the company provide unique perspectives and ideas to broaden the evaluation beyond standard industry concerns.

CTSA results also promote environmental competitiveness. Many companies are discovering that proactive environmental business policies are necessary to remain competitive in today's global marketplace. In addition to the benefits of an improved company image, businesses are finding that they can no longer afford to waste energy or other precious resources or pollute the environment.